INSTRUCTIONS FOR THE CARE AND TEST OF

BOILER FEED WATER

AND FOR THE OPERATION, CARE AND REPAIR OF

FEED WATER APPARATUS

(Reprint of Chapter 6 of the Manual of Engineering Instructions)

U.S. NAVY DEPARTMENT
BUREAU OF ENGINEERING

Comments, [illegible] and suggestions regarding this publication are invited. Address, Bureau of Engineering, Navy Department, Washington, D.C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
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CHAPTER 6.

BOILER FEED WATER AND FEED-WATER APPARATUS.

SECTION I.—FEED WATER.

PART 1.—KINDS OF FEED WATER.

6–1. Water used for feeding marine boilers is obtained either from ashore or from distilling plants on board ship. Practically all water from ashore contains substances which are injurious to the boiler when used as make-up feed. Hence, ships shall, except in emergencies, use water that has been distilled on board ship. **Use of shore and distilled water.**

6–2. (1) If water for feeding boilers is obtained from ashore, it shall be distilled before being used as feed water. The practice of obtaining water from ashore and then distilling it, while not positively prohibited, is to be discouraged. In order that the ship's personnel may at all times operate the distilling plant under the same conditions as are met at sea, only sea water, if practicable, shall be distilled in the ship's distilling plant. **Treatment of shore water.**

(2) When the use of undistilled shore water is unavoidable, especial care must be taken that it is always maintained more than one-tenth of one per cent and less than five-tenths of one per cent normal alkaline strength. (See art. 6–99.)

PART 2.—IMPURITIES.

Kinds of impurities. 6–20. The impurities generally found in feed water which are the most injurious to the boiler are principally the carbonates, sulphates, and chlorides of lime, magnesia, and sodium; iron and aluminum salts; silicates; mineral and organic acids; grease; carbon dioxide; and air.

Impurities in water distilled on board ship. 6–21. Water distilled on board ship from sea water may contain soluble salts and other substances which are injurious to the boiler when the water is used as make-up feed. This condition is due to the rapid rate of evaporation caused by improper operation of the distilling plant, which in turn causes small particles of salt to be carried over. Some acids may be carried over, and some are formed as a result of reactions between substances in solution. Except in an emergency, water containing more than one-half grain chlorine per gallon should not be sent to the feed tanks.

To prevent impurities from system entering feed water. 6–22. Whatever the source, feed water shall be maintained as free as possible from impurities. This requirement involves careful attention to the entire machinery plant through which the water passes, either in the form of steam or as water, for even if water used as make-up feed be excellent water at the time of its entry into the system, it may soon absorb impurities from the various parts of the installation.

Sources of impurities. 6–23. The principal parts of the system where these impurities may enter the feed water are:

Condensers, main, auxiliary, dynamo, and augmentor.

Channel-way piping.

Main air pump snifting valves.

Bottom blow valves.

Evaporators.

Distilling condensers.

Fuel oil and evaporator feed-water heaters.

Leaky feed suction and drain lines, running through bilges and oil tanks.

Leaky valves on lines through which both salt and fresh water may be circulated.

Salt water bath heaters.

Leaky seams, rivets, etc., in reserve bottoms.

Heaters in lubricating oil settling tanks and around oil suctions in fuel-oil stowage tanks.

Piston rods, valve stems, cylinders, etc.

Use of devices for removing air and grease. 6–24. In order that as much of the impurities as possible may be removed and that the absorption of impurities may be kept as low as possible, all devices for removing air and grease from the water shall be habitually used and all parts of the system where feed water may absorb impurities shall be kept in efficient condition.

Precautions against leaks. 6–25. To replace water lost by leakage, it is necessary to add to the system make-up feed water with its contained impurities. In order that the amount of make-up feed may be reduced to a minimum, all boilers, piping, glands, valves, etc., shall be kept tight and in efficient condition.

6–26. Since none but the volatile impurities pass out of the boilers with the steam there results a continual concentration in the boiler of

the impurities in the feed water. The nonvolatile impurities remain in the boiler and cause corrosion, scale, and increased density of the water.

6–27. Corrosion may take the form of a rust coating over the entire surface, called "general corrosion," or it may be restricted to small areas, in which case it is called "pitting." It is due principally to the tendency of metals to dissolve in water, aqueous solutions, and films of moisture. The metal so dissolved is then readily *oxidized when in contact with free oxygen either in the solution or above the surface.* **Kinds of corrosion.**

6–28. (1) The generally accepted theory to account for considerable corrosive action is the electrolytic theory, in which it is assumed that galvanic cells are formed in the boiler. **The electrolytic theory of corrosion.**

(2) There are three essentials to a galvanic cell, viz, an electropositive substance or pole, an electronegative substance or pole, and an electrolyte or carrier. In a boiler the electropositive and electronegative substances exist due to the nonhomogeneity of the metal. This nonhomogeneity causes a difference in potential between different parts of the metal, similar to the difference in potential between the poles of a cell. If the water contains acid, salt, or similar impurities from which acids or current-carrying electrotytes are derived, the cell is complete and a current flows with the result that the electropositive substance is eaten away or corroded.

(3) The rate of pitting is proportional to the value of the current which, in turn, is proportional to the strength of the electrolyte and the difference in potential between the nonhomogenious parts of the boiler metal.

(4) Acids introduced in the feed water or acids formed therein by chemical reactions between the impurities in the feed water due to heat and pressure, render the feed water a good electrolyte, the strength of which depends upon the amount of acids introduced or formed.

6–29. (1) If the formation or the action of any one of the three essentials above mentioned can be prevented, a cell can not be formed and corrosion due to galvanic action can not take place. As it is practically impossible to obtain metal that is homogeneous throughout a boiler, it becomes necessary to prevent the boiler feed water from acting as an electrolyte. **Prevention of corrosion by introduction of reagents.**

(2) To accomplish this end, the acid in the boiler feed water is neutralized or the water made slightly alkaline (greater than one-tenth of 1 per cent but less than one-half of 1 per cent) (see art. 6–99) by introducing reagents into the feed water.

6–30. Concentration of the impurities in the boiler feed water and the action of heat and pressure on them cause the impurities to be deposited on the boiler surfaces in the form of scale. Scale, while not dangerous when the boilers are steaming at the lower rates of combustion, becomes dried out when the boiler is forced and forms a heat insulator between the boiler heating surface and the water, and thus exposes the metal to overheating and burning. The rise in temperature of the metal in a boiler, due to a coating of scale, is shown in Figure 6–1. **Scale, cause and effect of.**

6–31. As impurities of the sodium and other scale-forming salts dissolve in water, the density of the water increases. When impurities enter a boiler in amounts so large that the density of the **Priming, cause and effect of.**

boiler water is high, the boiler primes—that is, water carries over into the steam line. This priming reduces the efficient action of the steam because the water carried over with the steam spreads the impurities throughout the entire machinery plant, causing inefficient operation. In aggravated cases when large volumes of water are carried over, priming results in serious injury to machinery, such as the stripping of turbine blades or bursting of cylinders, pipes, and valves. One of the first serious effects of priming is the jamming of governors.

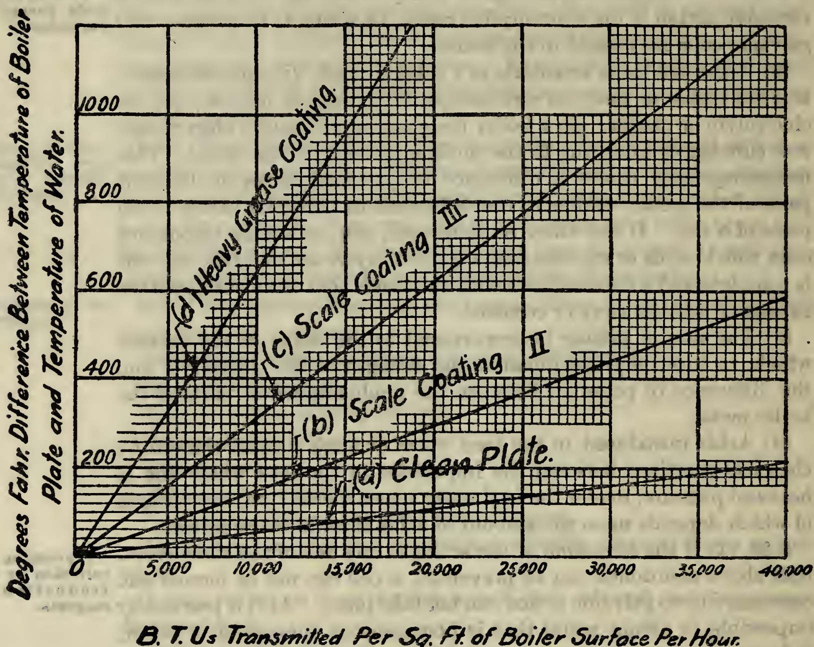


Fig. 6-1.

NOTE.—Curve "a" shows results with clean plate when "L," coefficient of heat transmission from metal to water, was 166.

Curve "b" shows results when scale coating was such that "L" was 67.

Curve "c" shows results when scale coating was such that "L" was 31.

Curve "d" shows results of heavy grease coating with "L" equal to 13.4.

PART 3.—PREVENTION OF ACCESS OF AIR TO FEED WATER.

6-45. As impurities in water can not cause corrosion without the presence of oxygen, the most important precaution to take with boiler feed water is the removal of the dissolved or entrained air. This should be done before the water enters a boiler.

Gland packing. 6-46. *In order to prevent not only the loss of vacuum, but also the admission of air to the feed system, the packing of all glands connected to the low-pressure cylinders and other parts of the plant which operate below atmosphere pressure must be kept tight.*

6–47. As the solubility of oxygen in water decreases rapidly with a rise in temperature, by far the greater part of the air can be removed by heating the water to or near the boiling point in an open heater. If, in addition to this heating, a vacuum can be maintained over the water, the dissolved air is practically all removed. Even if no diminished pressure can be maintained over the water, the mere heating to or near the boiling point drives off most of the dissolved air, in which case, if the heater used is not of the open type, the air should be caught in an air chamber and then bled from the system. **Effect of heating boiler feed water**

6–48. Another method of removing air from feed water is to send the water on its way to the boiler through a tank or box containing small pieces of finely divided scrap iron, in such a way that the water must filter through it, thus allowing the oxygen to corrode the scrap iron instead of the boiler. Such a device is called an oxygen extractor. This tank must be easily accessible and the tank taken out and the contents cleaned or renewed when necessary. They are not installed on board naval vessels, and heating in closed heaters to remove the air from the water is resorted to. (See art. 6–132.) **Oxygen extractor.**

6–49. (1) To prevent air contained in the feed water from entering into active circulation in the boilers, the entering feed water should be forced toward the steam space. The feed arrangements to accomplish this should be as follows: **Arrangement of internal feed pipe.**

(*a*) Extend the internal feed pipe the entire length of the boiler drum, and arrange the holes so that feed water will be discharged upward toward the steam space. Babcock & Wilcox boilers fitted with outside downcomers from the steam drum to the cross box should have nozzles with cut-out valves on the ends of the internal feed pipe, so that the feed water may be discharged into the downcomer to furnish the additional water needed for the lower rows of tubes when the boilers are being forced to or near designed full power. The feed pipe must be placed in the lower part of the drum, and the holes in the top of this pipe must be *at least 6 inches below the normal water level.* (Careful attention must be given to maintaining the water level above the holes in the internal feed pipe to prevent water and steam hammers that might disrupt connections of the internal feed pipe or that might cause trouble at the feed check valves.)

(*b*) The surface blow piping should be led either along the front side in the boiler drum, 2 inches below the normal water level, with holes in the upper side throughout the full length of the pipe, or to a scum pan placed 2 inches below the normal water level in the vertical center line of the boiler.

(2) Ships in which the arrangement of the internal feed piping or scum piping differs materially from that described above should apply to the bureau for a print of the type plan showing the approved arrangement.

PART 4.—PREVENTION OF ACCESS OF CHLORINE (SALT) AND OTHER MINERAL AND ORGANIC MATTER TO FEED WATER.

6–50. (1) The impurity which causes the engineer officer the greatest amount of trouble and the one which will disable an engineering plant quicker than any other is sea water. The large amount of chlo- **Salt and its effects.**

rine, in the form of sodium chloride (common salt), contained in sea water combines with other impurities—

(*a*) To increase enormously the corrosive properties of feed water.

(*b*) To form a thick hard scale.

(*c*) To cause priming of the boiler.

Means taken to detect entry of chlorine into system.

(2) For these reasons every precaution should be taken to prevent the entry of salt water into the system. In order that salt in an unusual amount may be detected before any serious impairment is done to the plant as a whole, condensate, from each condenser in use, shall be tested at least hourly while at anchor and at least every fifteen minutes while under way. (See art. 6–82.) If the amount of salt found in the condensate exceeds the amount allowed by the engineer officer as the upper limit, the fact must be reported to him at once and immediate action taken to locate the trouble. Under ordinary conditions this limit should not exceed one-half grain of chlorine per gallon.

Conditions which limit allowable chlorine content of condensate.

6–51. (1) The engineer officer in deciding the allowable number of grains of chlorine per gallon in the condensate before conducting tests to discover salt-water leaks has several points to consider. With a constant vacuum, and should no salt be carried over from the boilers with the steam, condensate which showed 0.5 of a grain per gallon at 10 knots should show less when the ship is speeded up to 20 knots, even though allowance is made for a slight increase in the pressure on the salt-water side of the condenser, due to the pressure of the circulating water. The reason for this decrease in the salinity of the condensate is that, although the leak may be constant, the amount of steam per hour being condensed into water is very much greater at 20 knots than at 10 knots, while the actual amount of chlorine by weight which enters is about the same, but it is distributed throughout a greater volume of water.

(2) When speeding up and the condensate tests the same at the higher as it does at the lower speed, it is a question whether a new leak has developed or if salt is being carried over from the boilers by the steam. The deciding factor in such cases is whether or not the water in the boilers is increasing in salinity at an unusual rate.

Natural increase in chlorinity of boiler water.

(3) Under ordinary conditions the salinity of the water in the boilers should not increase more than 2 grains per day when using make-up feed containing 2 grains or less chlorine per gallon. When this condition exists it is a safe assumption that the condensers are tight.

Tracing entry of salt into systems.

6–52. (1) To locate salt-water leaks, test the fresh water from each element for presence of salt or cut out the elements one at a time until the condensate freshens. (See art. 6–23.) Each time one of these elements is cut out a test for salt in the condensate (hot well) should be taken, first allowing the plant to operate a while without this element in commission in order that any salt which is present in the tank due to that element may have time to distribute itself throughout the system. Having found which element is giving the trouble, work must immediately be started to remedy the defect. (The methods of testing the condensers to locate a leak are described in the chapter on "Condensers," chap. 15.)

(2) If the boilers salt up without the hot well showing signs of pronounced increase of salinity, the trouble must be looked for in leaky boiler blow valves in idle boilers, leaky rivets in the reserve bottoms, or open or leaky valves on lines so arranged that they lead to sources of both fresh and salt water.

6–53. The chlorine content of boiler water shall never, except in an emergency, be allowed to exceed 30 grains in small tube water-tube boilers, 50 grains in large tube water-tube boilers, and 100 grains in fire-tube boilers. Whenever the chlorine content reaches the above limits, the boiler shall be given a blow down, or, preferably, fires shall be allowed to die out, and the boiler allowed to cool. It shall then be emptied and refilled with fresh water. **Amount of chlorine allowed in boilers.**

6–54. Except in an emergency water which contains more than 2 grains of chlorine per gallon shall not be used for make-up feed purpose. Ordinarily, water containing more than one-half grain of chlorine per gallon, should not be sent to the feed tanks. **Chlorinity of make-up feed.**

6–55. (1) The vapor from evaporators must not be discharged directly into the exhaust steam pipe or into condensers, but should be sent to the distilling condensers and then discharged into the measuring tanks. The water from the distilling condensers should be directed at will from one or another of the measuring tanks. When a measuring tank is filled, the water in it must be tested before being sent to the feed tanks. **Use of sampling tanks with evaporators.**

(2) When piping arrangement permits, distill to one bottom, then if the water is found to contain less than one-half grain of chlorine per gallon, pump it to reserve feed tank. If it contains more than one-half grain of chlorine per gallon, but is potable, send it to the ship's tanks. Otherwise, use it for washing purposes.

6–56. (1) Direct connection between piping carrying salt water and piping carrying fresh water shall not be used. Such arrangenents may be encountered in the older installations, but are very seldom, if ever, really necessary, and blank flanges should be installed by the ship's force to separate the systems. In all cases corrections should be made to the machinery drawings to show where blanks are installed; the change shall be logged and reported to the bureau by letter. **Connections between salt and fresh water piping.**

(2) Inspect these blank flanges quarterly.

6–57. If the steam leads to salt-water baths have not been disconnected, they shall be blank flanged immediately, the change made on the plans, and the bureau notified of the change. **Blank flange steam leads to salt-water baths.**

6–58. Auxiliary feed pumps should never be used as fire and bilge pumps. On some older vessels pumps are fitted for use for either of these purposes. In such cases pumps ordinarily used as auxiliary feed pumps should have all salt-water valves made tight and wired shut, and those used ordinarily as fire and bilge pumps should have the feed-water valves made tight and wired shut, the wiring being removed only in case of emergency or for purposes of examination and test. The interval between such tests and examinations should ordinarily be about three months. (See art. 14–98 (5).) **Auxiliary feed pump as fire and bilge pump.**

6–59. Leaky evaporator coils should be suspected when there occurs an increase in the amount of make-up feed used, although the output **Leaky evaporator coils.**

of the evaporators remains constant or shows a marked increase and when there is evidence of salting up the system. Salt will enter the system through a leaky evaporator coil during a complete blow down when the pressure in the shell is greater than that in the coils. At this time brine is forced into the coils and eventually finds its way to the hot well, whence it is spread throughout the system. *Therefore, in order to locate this leak, test the water in the hot well for salt after each complete blow down of the evaporators.*

Leaky feed lines in bilges. 6–60. The system may be salted up by leaky feed suction lines which run through the bilges. When a suction is put on the line to take feed and there is salt water in the bilges, the bilge water is drawn into the feed line and sent through the system.

PART 5.—PREVENTION OF ACCESS OF OIL AND GREASE TO FEED WATER.

Prevention of entry of grease into feed-water system. 6–62. Oil and grease in the feed water are soon deposited on the water sides of the heating surfaces of the boiler and form a heavy scale. Oil and grease enter the feed-water system chiefly through the main engines and auxiliary machinery, due to lubricants being used in cylinders, on piston rods, valve stems, etc. (See art. 6–23.) Hence, the following shall be strictly adhered to:

Lubrication of cylinders and valve chests. (*a*) No tallow or oil of vegetable origin shall be used for the interior lubrication of the steam cylinders or valve chests, and as little mineral oil as is consistent with efficient operation shall be used for this purpose. (This prohibition shall apply for every steam cylinder or valve chest for whatever purpose used.) Under ordinary conditions of working with saturated steam, the water of condensation derived from the steam furnishes ample lubrication for the internal working parts; but if this does not prove sufficient, pure mineral oil only shall be used. (See art. 14–5.)

Use of grease, oil, and graphite on joints. (*b*) Grease or oil shall not be used in making joints of steam or water piping, or in packing valve glands of any steam or fresh-water valve or on boiler gaskets or joints. Graphite (an active corrosive agent) when used for these purposes shall be used sparingly, in order to prevent it from getting into the feed system.

To prevent oil and grease entering cylinders. (*c*) Care shall be taken that oil used for lubricating the piston rods or valve stems is not drawn into cylinders or valve chests. All excess oil should be wiped off the brush before the rods and stems are swobbed. With main engines of the reciprocating type fitted with forced lubrication systems, care shall be taken to prevent the oil from being splashed on piston rods or valve stems, particularly from cross heads or guides.

Filters to be used. 6–63. When filters or grease extractors are fitted they shall always be used.

Cleaning filtering material. 6–64. Filtering material shall be cleaned or renewed as often as necessary to keep it effective and to prevent it becoming saturated or clogged with grease. (See art. 6–183(2).) Spare cartridges of grease extractors with clean (or cleaned) filtering material should be kept on hand at all times, and the renewals made, if practicable, once every day or oftener while steaming. (See art. 6–200.)

6–65. Water from steam drain lines should always be passed through a filtering medium, such as the filter chamber of the main feed and

filter tank. Drains from fuel-oil heaters, coils in lubricating oil tanks and fuel-oil bottoms shall if possible always be passed through an inspection tank.

6–66. Whenever the presence of grease in a boiler is indicated in the gauge glasses, the grease should be removed by giving the boiler a surface blow. The glasses should be cleaned out by blowing so that any further accumulation of grease may be detected. **Removing grease with surface blow.**

6–67. Both salt and grease, or a combination of both, are very injurious when they are present to a marked degree in the system, particularly in fire tube boilers, and may cause furnace tubes to sag. Thorough inspections and tests shall be made periodically, at times herein prescribed, of the different apparatus provided for the detection of both grease and salt solutions in the feed water; and such action shall be taken to prevent damage as is found necessary as a result of these inspections and tests.

PART 6.—FEED-WATER TESTS AND TEST APPARATUS.

6–79. To prevent the deteriorating effect on boilers of impurities in feed water, it is necessary not only to keep the water as free as possible of impurities, but also to treat the feed water so that impurities therein will do a minimum of damage. As only slight general corrosion can take place in water that is slightly alkaline or that contains no corrosive acids or salts which can form corrosive acids, it becomes necessary, first, to make a careful analysis of the boiler water in order to determine the exact amount of such impurities present and second, to introduce a sufficient amount of reagent to counteract the effect of the impurities or to discard the water if the effect of impurities can not readily be counteracted. **Necessity of analysis and treatment of water.**

6–80. To make an exact quantitative analysis of boiler feed water to determine the amount of impurities present is impracticable on board ship. As a substitute, vessels are provided with a testing apparatus, called the "Navy standard boiler water-testing apparatus." (See art. 6–86.) By means of this apparatus the exact chlorine content and the acidity or alkalinity of the feed water can be determined. This having been determined, the amount of reagents necessary to introduce to render this water harmless as make-up feed can be deduced. **Use of "Navy standard boiler water-testing apparatus."**

6–81. (1) In order that the quality of boiler feed water may be known at all times the following tests shall be made: **Prescribed tests of feed water and condensate.**

(*a*) *Every fifteen minutes.*—Underway: Condensate from each condenser in use for salinity.

(*b*) *Hourly.*—At anchor: Condensate for each condenser in use for salinity.

(*c*) *Daily.*—Water in all steaming boilers, main feed and filter tanks, and reserve bottoms for alkalinity and salinity.

(*d*) *Weekly.*—Water in all idle boilers for alkalinity and salinity. Corrosive tests of steel suspended in water.

(2) It should be noted that: **Points to be noted.**

(*a*) The water for the weekly alkalinity and salinity test of idle boilers shall be drawn from the lower part of the boiler. (See art. 6–102.)

(*b*) The Navy standard boiler water-testing outfit shall be used for the daily and weekly alkalinity and salinity tests.

15 minute and hourly test.

6–82. The 15 minute test under way and hourly test at anchor are made as follows:

(*a*) Draw off the condensate in a large-necked clear glass bottle of about 6 ounces capacity and allow it to settle (to clear it of air bubbles). Add two or three drops of 10 per cent solution of silver nitrate. If the water becomes streaky or cloudy, it indicates that there is chlorine in the water and the person making the test will report this fact to the officer on watch, who will have the water tested for chlorinity, using the regular Navy standard water-testing outfit. The result of the latter test will be entered in engine-room log.

(*b*)(1) Another method of conducting this test which requires more exactness, but which gives a more correct indication of the amount of chlorine present, is given below. It employs in the rough the same method used as when testing with the Navy standard boiler water-testing outfit. (See arts. 6–87 and 6–88.)

(2) Provide a large-mouthed bottle of about 100 c. c. (cubic centimeters) capacity with a strip of adhesive plaster or a file mark at the 50 c. c. level, a small bottle of potassium chromate indicator and one of standard silver nitrate solution (about 25 c. c.) and two medicine droppers, one of which should be graduated by drawing in exactly 1 c. c. of liquid and filing a mark on the glass at that point. The graduated dropper is to be used for the silver-nitrate solution and the other dropper for the chromate indicator.

(3) In making the test, wash out the bottle with water drawn from the same source as that to be tested, fill the bottle to the 50 c. c. level, add 5 drops of chromate indicator, and stir well.

(4) Drop in the nitrate until the liquid in the container turns reddish brown. With 50 c. c. of water, each cubic centimeter of nitrate from the dropper indicates 1 grain of chlorine per gallon. The bulb should be moved back or forth on the dropper until one squeeze takes up 1 c. c.

(5) The silver nitrate used should be of the same strength as that used in the Navy standard boiler water-testing outfit.

(6) Record result of test in engine-room log and if the test shows a greater amount of chlorine per gallon than the allowable amount specified by the engineer officer, report that fact to him at once.

(*c*) (1) A variation of the method described above consists in using a large-necked bottle of about 50 c. c. capacity. On the side of this container scratch a mark at the water level reached when it contains 10 c.c.

(2) To test, fill bottle to the 10 c. c. mark with the water to be tested, and add two drops of the indicator. With an eye dropper add standard silver-nitrate solution, drop by drop, until the color reaction occurs. Each three drops added indicates 1 grain of chlorine per gallon.

(3) Record result of test in engine-room log and proceed as outlined in subparagraph (*b*)(6) this article.

Precautions with silver nitrate.

6–83. Never keep large quantities of nitrate in the engine room as it deteriorates rapidly with heat. It should be kept in a dark-colored bottle, as it is decomposed by the action of light.

6–84. The test for corrosive properties of the water shall be conducted as follows: **Test for corrosion.**

(*a*) Suspend a small piece of clean, bright boiler steel in a corked bottle filled with water drawn from the boiler. Note any corrosive action that takes place. (See art. 6–85.) If the water is suitable for use in the boiler the action will cover the entire wetted surface, but, if corrosive, local action or pitting will result within twenty-four hours.

(*b*) This test is to determine whether or not the water is of such alkaline strength as to promote pitting.

6–85. Experiments regarding the use of reagents such as boiler compounds and corrosion definitely prove that good steel will corrode almost evenly over its entire wetted surface when placed in distilled water. As small amounts of compound are added to the water to give it a very low alkaline strength (more than one-tenth of 1 per cent but less than one-half of 1 per cent), the rate of corrosion is slightly decreased, but the form of corrosion remains the same. This slight general corrosion is so small in amount that its effect may be disregarded for all practicable purposes. Corrosion of metal in distilled water starts out in the form of local corrosion or slight pitting, and subsequently rust spreads over the entire wetted surface. This accounts for the fact that pitting is often reported after a 24-hour test. In so short a time even distilled water will show evidences of local corrosion or pitting, but if the test is carried on for several days, the test piece of steel will eventually corrode all over if the alkaline strength of the water is less than one-half of 1 per cent normal alkaline strength. **Corrosion of steel in distilled water, and water made slightly alkaline.**

6–86. The Navy standard boiler water-testing apparatus consists of the following parts: **Navy standard boiler water-testing apparatus.**

(1) Burette in place ready for use for determination of alkalinity. Graduated to 0.1 c. c. at 15° C., 50 c. c. capacity.

(2) White porcelain dish of 200 c. c. capacity.

(3) Bottle of one-half normal nitric acid, 1,000 c. c. capacity. One-half nitric acid normal (HNO_3) contains 32 c. c. of "chemically pure" acid (69.5 per cent strength) to 1 liter of solution.

(4) Measuring cylinder graduated to 1 c. c. at 15° C., 100 c. c. capacity.

(5) Burette, similar to 1, for determination of chlorine content.

(6) Spare burette, similar to 1 and 5.

(7) Glass rod for stirring samples in 2

(8) Pipette of 1 c.c. capacity.

(9) Bottle of methyl orange solution, fitted with dropper through stopper, 100 c. c. capacity. The solution is made by dissolving one-tenth gram of methyl orange powder in 100 c. c. of distilled water.

NOTE.—This solution is an "indicator" which will turn alkaline solutions a pale yellow and acid solutions a faint pink color.

(10) Bottle of normal solution of anhydrous sodium carbonate, 500 c. c. capacity. The solution is made by dissolving 26½ grams of chemically pure anhydrous Na_2CO_3 in distilled water, and adding enough distilled water to make 500 c. c. of solution.

(11) Glass beaker, 150 c. c. capacity, for pouring acid, alkali, or nitrate of silver solutions into burette.

(12) Bottle of red litmus-paper strips for general use in testing strong alkalies. Alkalies turn the red paper blue.

(13) Bottle of blue litmus-paper strips for general use in testing strong acids. Acids turn blue paper red.

(14) Graduated test tubes for measuring large amounts of chlorine in water and for diluting water for chlorine measurements. The graduations are in 5 c. c. increments, but are marked 0, 50, 100, etc.

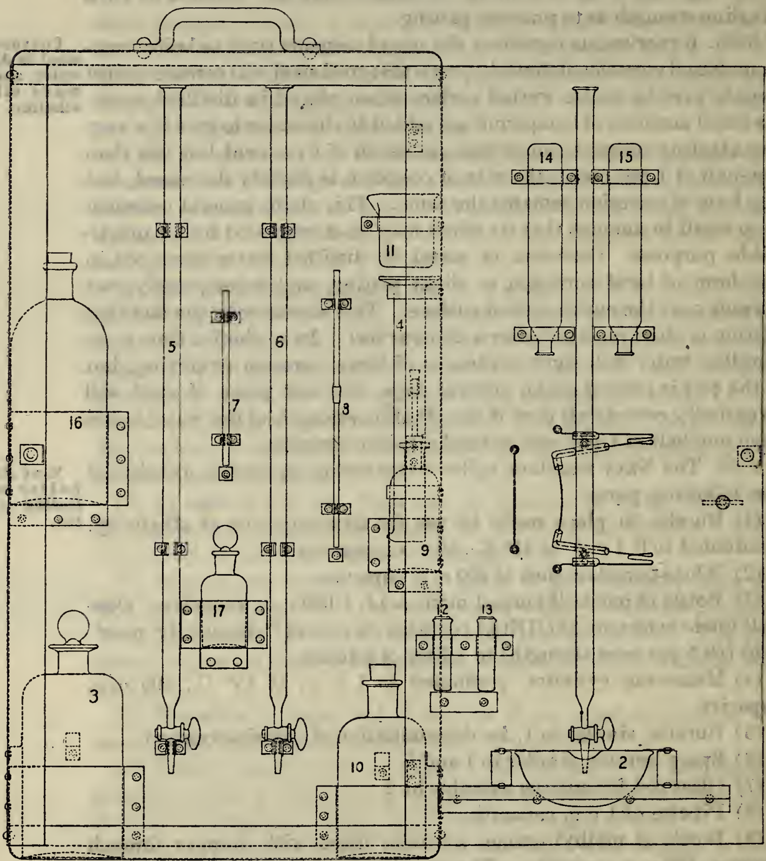


FIG. 6–2.

(15) A brown glass-stoppered bottle, 1 liter capacity, containing a solution of silver nitrate. The silver nitrate solution is made by dissolving 4.101 grams of chemically pure silver nitrate crystals in distilled water, and making the total volume of the solution up to exactly 1 liter.

(16) A glass-stoppered bottle of about 150 c. c. capacity containing potassium chromate solution for use as an indicator. The potassium chromate solution is made by dissolving 1 gram of chemically pure potassium chromate in 100 c. c. of distilled water.

(17) The outfit furnished ships consists of the case and the instruments and containers described above, but does not include the chemicals. The latter must be obtained upon requisition, in sufficient quantities to last for a considerable length of time, and the solutions compounded aboard ship as required. Where the services of a navy-yard chemist are available it is well to ask his assistance in making up the first lot to observe methods employed by him.

6–87. (1) To make the alkalinity test, draw a sample of water to be tested into a glass or porcelain receptacle *which has just previously been washed out with water from the same source.* **Alkalinity test.**

(2) Fill the burette 1 with acid from bottle 3, using beaker 11. Open pet cock at bottom of burette and draw a few drops of acid through it into 11. Repeat this if necessary until all air bubbles have been expelled from lower end of burette and it is filled to tip with acid when cock is closed.

(3) Measure exactly 50 c. c. of the sample of water to be tested into cylinder 4 and pour into dish 2, which has just previously been washed out with other water from the same sample, or with distilled water, and wiped dry.

(4) Drop two drops of the methyl orange solution from bottle 9 into the sample in dish 2. If the sample is in the least alkaline or neutral, it will turn a pale yellow when stirred with the glass rod 7.

(5) Read the graduation at the top of the acid in the burette; then from pet cock at the bottom drop acid into the sample in dish 2, stirring continuously with the glass rod 7 until sample turns a faint pink. Close the pet cock and read the graduation on the burette at the top of the acid. The difference between the two readings indicates the number of cubic centimeters of acid required to neutralize the alkali in the sample.

Each cubic centimeter of one-half normal acid used in neutralizing the alkali in a 50 c. c. sample indicates 1 per cent of normal alkaline strength. (See art. 6–89.)

NOTE.—These instructions require acid to be added until the sample turns a faint pink. This indicates that the alkali has been a little more than neutralized and the sample has become slightly acid. The error, however, will be negligible for the purpose of testing boiler water if the test is carefully made and the pet cock closed at the instant that the faintest pink color is attained in the well-stirred sample. For this reason the acid should be added drop by drop and the test conducted in a good light.

6–88. (1) (*a*) The sample in dish 2 is now slightly acid. Before testing for chlorine the sample must be made neutral or slightly alkaline. **Chlorine test.**

(*b*) Using pipette 8, drop sodium carbonate solution from bottle 10 into the sample until it just turns yellow, indicating that it is neutral or slightly alkaline. One drop should be sufficient.

(2) (*a*) Replace burette 1 with burette 5, and fill 5 with silver nitrate solution from bottle 16, taking precautions as before to see that it is filled to the tip. Using pipette 8, drop four drops of chromate indicator from bottle 17 into sample in dish 2. Read the graduation at the top of the nitrate in the burette, then from pet cock drop nitrate

into the sample in dish 2, stirring continuously with the glass rod 7, until the sample turns a reddish-yellow color throughout. Close the pet cock and read the graduation on the burette at the top of the nitrate. The difference between the two readings indicates the number of cubic centimeters of the nitrate required to precipitate all of the chlorine in the sample.

(b) *With this strength of silver nitrate solution each cubic centimeter used in the 50 c. c. sample indicates 1 grain of chlorine in each gallon of boiler water.* (See art. 6–95.)

(3) The stop cock should be closed as soon as the change in color from yellow to reddish-yellow in the well-stirred sample occurs. If the nitrate is added until the sample is a deep red, erroneous results will be derived. For this reason the nitrate should be added drop by drop after the first sign of reaction occurs, and the test should be made in a good light.

(4) If a light be held under dish 2 while the nitrate is being added the color reaction will be better defined.

Determining normal alkaline strength.

6–89. (1) The percentage of normal alkaline strength, X, of a solution may be expressed thus:

$$X=\frac{A}{S}\times P$$

where A is the number of cubic centimeters of the acid required exactly to neutralize the alkali in the sample of the solution, S is the number of cubic centimeters of the sample, and P is the percentage of normal strength of the acid used.

(2) For example, if it is found that exactly 2.2 c. c. of a half-normal acid are required to neutralize the alkali in a 50 c. c. sample of a solution, then the percentage of alkaline strength of the solution is

$$\frac{2.2}{50}\times\frac{1}{2}=\frac{2.2}{100}=0.022$$

or the solution is 2.2 per cent of normal alkaline strength.

Exactness in all details of test required.

6–90. From the above equation it may be seen that any variation from the prescribed size of sample tested, or any variation from the prescribed strength of acid used, will directly affect the accuracy of the determination of the alkaline strength. As alkaline strength of boiler water must be kept as low as possible consistent with obtaining accurate measurements (the upper limit being one-half of 1 per cent), it is evident that, because of narrow limits, rough approximate analyses are not permissible. Every care, therefore, should be exercised in compounding the reagents and in making the titrations.

To obtain acid for test.

6–91. To provide a stock acid of standard known strength there will be kept in store at all naval stations and obtainable on not-in-excess requisitions a supply of nitric acid for use solely with this outfit. Requisitions should state that the acid is required for testing boiler water, and recipients should reject any bottle not bearing a label stating that it contains nitric acid of not less than 69½ per cent or more than 70 per cent of pure acid by weight.

Compounding an acid solution.

6–92. (1) To compound an acid solution of half-normal strength, exactly 32 c. c. of the standard stock acid should be mixed with 968 c. c. of distilled water. Bottle 3 is supposed to be of 1,000 c. c. capacity, but

commercial bottles vary in size. If the 1,000 c. c. level is once *accurately* determined by use of the burette and marked with a file scratch, the solution can be easily compounded whenever necessary by running 32 c. c. of the stock acid from a burette into the bottle and adding water up to this 1,000 c. c. mark.

(2) If, for any reason, the standard stock acid referred to in article 6–91 is not available, a solution may be prepared by using any acid not containing chlorine (though nitric acid is to be preferred), as follows:

(*a*) Make up a solution by mixing with distilled water enough of the acid, according to what its strength is known or supposed to be, to make approximately a half-normal solution, and then proceed to determine the exact strength of the solution, thus:

(*b*) Measure exactly 50 c. c. of the acid solution in cylinder 4 and pour into dish 2. Add 2 drops of the indicator from bottle 9 and stir with the glass rod. The sample will turn pink. Fill burette 6 to the tip with normal sodium carbonate solution from bottle 10 and read the height of the solution in the burette. Run sodium carbonate solution into the sample, stirring continuously, and close the pet cock at the instant that the sample changes color from pink to yellow, indicating that the acid has been neutralized. Read the height of the solution in the burette and determine how many cubic centimeters of the sodium carbonate solution have been used.

(*c*) Remembering that a given quantity of an alkaline solution of a given strength will exactly neutralize the same quantity of an acid solution of the same strength; that the sodium carbonate solution is of normal strength; and that the sample of acid solution contains 50 c. c., it is apparent that if it required, say, 20 c. c. of the sodium carbonate solution to neutralize the acid, then the acid strength of the sample is $\frac{20}{50}$, or $\frac{2}{5}$ of normal acid strength.

(3) Suppose that in testing a sample of boiler water in the manner described in article 6–87 (1) to 6–87 (5), it is found that 3 c. c. of this two-fifths normal acid is required to neutralize the alkali in the 50 c. c. sample; then, employing the equation given in article 6–89, $X=\frac{A}{S}\times P$, the alkaline strength of the sample is $\frac{3}{50}\times\frac{2}{5}=\frac{6}{250}=0.024$; in other words, the boiler water is 2.4 per cent of normal alkaline strength.

6–93. When the water in the boilers is very muddy or when it has been discolored by the use of considerable boiler compound, it should be allowed to stand in the original containers until the sediment in the water has settled. This will aid the one making alkalinity test to more readily detect the pink color reaction. **Procedure with muddy or discolored feed water.**

6–94. Freshly prepared methyl orange indicator gives a much more distinct color reaction than does indicator which has been allowed to stand for a considerable length of time. For this reason only small quantities of the indicator should be made at frequent intervals, instead of large quantities at long intervals. **Effectiveness of freshly prepared methyl orange.**

6–95. The chlorine test described in article 6–88 depends upon the fact that 4.101 grams of silver nitrate per liter of distilled water is just sufficient to precipitate all the chlorine in an equal volume of a sample **Basis of chlorine test.**

when the sample contains 50 grains of chlorine to the gallon of 231 cubic inches. Hence, the chlorine content of a sample may be expressed thus:

$$X=\frac{N}{S}\times 50.$$

Where X equals the grains of chlorine per gallon of sample, S equals cubic centimeters of original sample tested, and N equals cubic centimeters of nitarte of silver solution of 4.101 grams per liter required to just precipitate all the chlorine in the sample.

NOTE.—The sample in dish 2 at the beginning of the chlorine test consisted of more than 50 c. c. of total contents, being made up of the original 50 c. c. of boiler water, and the amounts of indicators, acid, and alakli added subsequently. However, the reaction for the determination of chlorine upon the precipitation of all chlorine contained in dish 2, and since none has been either added or subtracted by the addition of the other reagents, the amount of nitrate of silver required to precipitate all the chlorine in the augmented sample is a direct measure of the chlorine content in the original sample of 50 c. c., expressed in terms of grains per gallon.

Rough determination of high chlorine content.

6–96. The test described in article 6–88 will determine the chlorine content within a fraction of a grain and should be employed when testing water from condensers, distillers, and feed tanks, and generally any water known or supposed to contain less than 50 grains of chlorine to the gallon. For the rough determination of high chlorine content the graduated test tubes 14 and 15 may be used, as follows:

(*a*) Having made the sample neutral or very slightly alkaline, as described in paragraph 6–88 (*b*), decant into 14 (or 15) until the top of the sample is level with the graduation marked "0." The tube now contains 5 cc. of the sample. Add one drop of the chromate indicator from bottle 17; slowly add silver-nitrate solution from bottle 16; keep shaking the tube. On nearing the full amount of nitrate solution required the sample will become reddish for an instant, but will turn back to yellow when shaken. Add nitrate solution drop by drop, and soon as the sample shows a reddish yellow and remains that color when shaken, stop adding nitrate. The reading of the graduated tube at the top of the sample will show the grains of chlorine per gallon. This is because the graduations, beginning from the bottom of the tube, are in increments of 5 c. c., and, as stated in article 6–95, a given volume of a nitrate of silver solution containing 4.101 grams to the liter will just precipitate all of the chlorine in the proportion of 50 grains to the gallon. It follows that double the amount of nitrate solution will be required to cause the same reaction in water containing chlorine in the proportion of 100 grains to the gallon, etc.

NOTE (*a*).—The fact that one or more reagents must be added to the sample before the silver-nitrate solution is added, and the proportioned volumes thereby disturbed vitiates somewhat the accuracy of the results of this method of test. But as the method is necessarily a rough one at best, the error introduced by adding the reagents will be negligible unless a relatively large quantity of acid or alkali has been required to make the sample nearly neutral.

Note (*b*).—Using this method, chlorine up to about 900 grains per gallon may be measured. If the sample contains more than this, proceed as follows: Take 10 c. c. of the sample and dilute with 90 c. c. of distilled water. Take 5 c. c. of the diluted sample and proceed as before. Each 5 c. c. of silver nitrate added now indicates 500 grains of chlorine to the gallon. Other proportions may be used in a similar manner.

Precautions when taking sample.

6–97 (1). It is important that before collecting samples of water the receptacle in which the sample is collected be well rinsed out with distilled water or water from the same source as the water to be tested. Otherwise precipitates from a previous sample may remain in the receptacle and be redissolved, and the test will give erroneous results. Similarly, the dish 2 should be thoroughly washed and dried after each test to remove traces of previous sample and of the reagents used in testing it; and, generally, before using burettes, beaker, measuring cylinder, etc., with any sample or reagent other than the same with which they were last used, they should be well rinsed out with a quantity of the liquid with which they are about to be used.

(2) Care must be taken to prevent perspiration from falling into the sample or receptacles. Contamination from this source will result in a false test.

Use of litmus paper.

(3) The litmus papers are furnished for rough qualitative alkaline or acid determinations. They should be used with caution. When used with water or any other liquid having an affinity for CO_2, the liquid should be boiling, since the presence of CO_2 will cause the color reaction to lag and results may be very misleading. The color reaction will be hastened if the litumus paper be first moistened in distilled water.

Pure distilled water to be used in solutions.

(4) Absolutely pure distilled water must be used in making up solutions in the testing set. If unable to procure distilled water from ashore, a still can be devised on board with which fresh water can be distilled and redistilled until free from any trace of chlorine. Never use rain water to make up solutions.

The "Concentration Indicator."

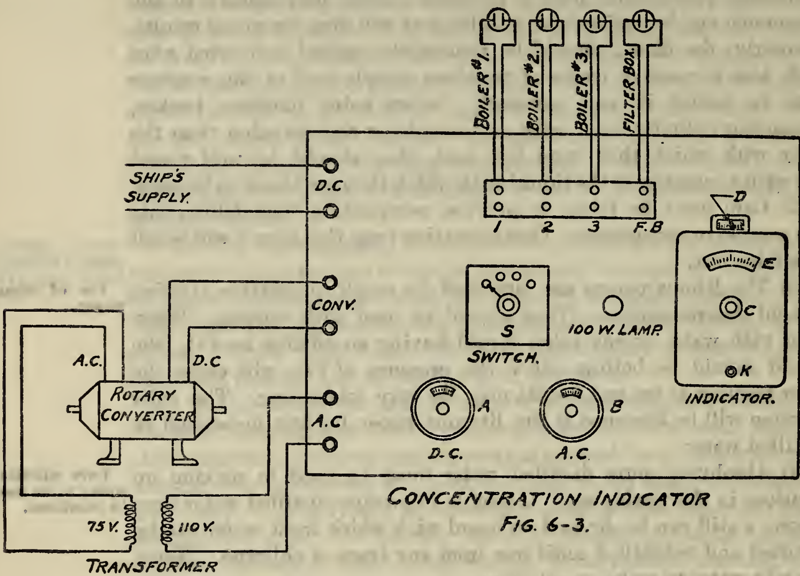
6–98 (1). An electrolytic salt detector, called a "Concentration Indicator," is being installed on vessels in the United States Navy. With this instrument it is not necessary to collect samples of water to be tested except when checking with the Navy standard boiler water testing apparatus. (See articles 6–87 and 6–88.) Measurements of the chlorine content of boiler water or of condensate can be made rapidly and continuously.

(2) The method of measurement used in the concentration indicator set depends upon the variation in resistance offered to the flow of electric current through water of varying salinity. The resistance offered to the flow of electricity from electrode to electrode decreases with an increase in the salinity of the water.

(3) The set consists of a cell which is attached to the boiler or receptacle in which is contained the water to be tested or is installed in the pipe line through the water to be tested is flowing. In the cell are two electrodes immersed in the water to be tested. A wheatstone bridge is used to measure the resistance offered to the flow of current from one electrode through the water to the second electrode. Alternating current is used with this apparatus, for should there be

a leakage of electricity while using direct current, electrolysis would result. Switches are provided for cutting in the cells attached to the various units. Resistance is inserted in the electrical circuit and a knob used to cut in and out this resistance. This knob is connected to a pointer which passes over a scale, so graduated that when the galvanometer in the electrical circuit indicates that there is no current flowing, the reading on the scale shows directly the amount of chlorine in the water under test in grains of chlorine per gallon.

(4) A line sketch of the electrical circuit is shown in Figure 6–3 The operation of the apparatus is as follows:



CONCENTRATION INDICATOR
FIG. 6-3.

(*a*) Close switches A and B, thus putting the rotary converter into operation, applying the alternating current to the apparatus.

(*b*) Turn selector switch S to the contact corresponding to the boiler, filter tank, etc., in which the salinity is to be determined.

(*c*) Intermittently press the push button K and turn the knob C until the galvanometer pointer D comes to rest opposite to the zero on the scale.

(*d*) Read the salinity directly from the dial E.

(*e*) To measure the salinity of the other boilers, turn selector switch S to the new contact and repeat the above operation.

(5) The panel installed with sets for boilers and condensers is hand operated as described above. An automatic continuous indicating device replaces this hand-operated panel when the apparatus is used in connection with the distilling plant. This device operates one of three lights, colored white, green, and red. The white light indicates water the chlorine content of which is from zero to one-half a grain per gallon; the green light, one-half to 5 grains per gallon; the red light, more than 5 grains per gallon.

(6) The results obtained with the concentration indicater should be checked daily by comparing them with the results obtained by testing with Navy standard boiler water-testing apparatus.

(7) If the results do not check, the apparatus should be overhauled, the electrodes cleaned of any collection of impurities which may have collected.

(8) The set as a whole requires the usual attention given to any electrical apparatus and circuit.

PART 7.—USE OF REAGENTS.

Rules for use of boiler compound.

6–99. The standard reagent used in the service is "Navy Standard Boiler Compound," and the bureau directs that:

(*a*) *Navy Standard Boiler Compound shall be employed on all vessels under control of the Navy.*

(*b*) *The prescribed tests of boiler water shall be made on all vessels using Navy Standard Boiler Compound. The Navy standard boiler water testing outfit shall always be employed for these tests.*

(*c*) *The alkaline strength of the boiler water shall be kept as low as possible, consistent with obtaining accurate measurements. To this end boiler water shall never be allowed to exceed one-half of 1 per cent of normal alkaline strength, nor shall it be allowed to be less than one-tenth of 1 per cent of normal alkaline strength. Hence boiler compound shall be used only in amounts necessary to insure that the water in the boilers is kept within the above prescribed limits, except when boiling out.* (See art. 2–626 (5).)

(*d*) *Careful compliance with the above instructions will inhibit any but slight general corrosion of boilers; this can never be serious, and cases of boilers requiring general retubing by reason of pitting should be rare in the future.*

(*e*) *Zincs in boilers in which compound is employed are so quickly disintegrated that, even if corrosion were prevented by their use, it is doubtful that the cost and labor of installation and upkeep would be warranted. Zincs and zinc baskets will, therefore, be removed from all boilers in which compound is employed.* (See art. 2–706.)

6–100. Below is given a table showing approximately the amount of boiler compound required to raise the alkaline strength of 1,000 gallons of water of known saline contents a degree or fraction thereof:

Pounds per 1,000 gallons for percentage normality indicated.

Percentage by volume of sea water.	Grains Cl per gallon.	0.1	0.2	0.3	0.4	0.5	1	2	3
100	1,109	1.62	3.23	4.82	6.48	8.10	16.2	32.4	48.6
50	549	1.10	2.29	3.30	4.40	5.50	11.0	22.0	33.0
35	270	0.85	1.70	2.55	3.40	4.20	8.5	17.0	25.5
15	166	.75	1.50	2.25	3.00	3.75	7.5	15.0	22.5
10	111	.70	1.40	2.10	2.80	3.50	7.0	14.0	21.1
5	55.5	.65	1.30	1.95	2.60	3.25	6.5	13.0	19.5
2	22.1	.62	1.24	1.86	2.48	3.10	6.2	12.4	18.6
1	11.0	.61	1.22	1.83	2.44	3.05	6.1	12.2	18.3
0.5	5.5	.60	1.20	1.80	2.40	3.00	6.0	12.0	18.0
0.2	2.2	.59	1.19	1.77	2.36	2.95	5.9	11.8	17.7
0.1	1.1	.59	1.19	1.77	2.36	2.95	5.9	11.8	17.7
0	0	.59	1.18	1.77	2.36	2.95	5.9	11.8	17.7

How to introduce compound into system. 6–101. (1) Boiler compound should never be put in the boiler in bulk. It should be thoroughly mixed with hot water in a large container and then placed in the boiler in amounts shown necessary by analysis of the water. If the boiler is closed but empty, the compound solution should be pumped into the boiler through the hose connection on the auxiliary feed pump, care being taken not to put all the compound in at one time, but in partial amounts throughout the time required for pumping up, in order that the compound may be equally distributed throughout the boiler.

(2) Many ships have installed a satisfactory permanent fitting on auxiliary feed pumps for introducing boiler compound into boilers as follows: Tap a three-fourths inch pipe into the suction end of the pump (on many pumps there is already such a hole filled with a pipe plug). Install a valve close to the pump and add the necessary pipe and fittings to enable the compound mixture being drawn from a bucket.

Circulate water to prevent precipitation of compound. 6–102. Compound will tend to precipitate in idle boilers, causing increased alkaline strength of the water in the lower parts of the boiler. It is, therefore, necessary to circulate the water in idle boilers weekly, using the auxiliary feed pumps.

To eliminate gasket troubles. 6–103. Most of the apparent injurious effect of compound on boiler and main steam line gaskets can be largely, and perhaps wholly, eliminated by a thorough cleaning of gasket seatings and eliminating all leaks however small. Gaskets are only attacked in the vicinity of leaks.

Priming when using prescribed amount of compound. 6–104. If priming occurs when using only sufficient amount of boiler compound to maintain the feed water at less than one-half of 1 per cent normal alkaline strength, the fact will be due generally to impure feed water in use.

Use of soda or lime and zincs. 6–105. (1) Whenever Navy Standard Boiler Compound can not be obtained, and then only, the water in the boilers shall be maintained at the prescribed alkaline strength by the use of sal soda or lime. As when using boiler compound, the water shall be kept at between one-half and one-tenth of 1 per cent normal alkaline strength.

(2) When habitually using sal soda or lime, zincs shall be used. When installed each one should be given a low voltage test to determine the existence of a perfect metallic contact between the zinc and the boiler metal.

(3) The zincs shall be fitted in baskets to prevent danger of plugging of tubes by disintegrated zincs.

Report when not using boiler compound as prescribed. 6–106. If Navy Standard Compound is not used when obtainable, or is not used in the prescribed amounts, the fact shall be reported to the Bureau of Engineering and the report shall state in detail the reasons therefor.

Preparation and introduction of lime into system. 6–107. As lime is not entirely soluble in water, it shall never be added directly to the feed water or boiler water. Unslaked lime, when used, shall be dissolved in cold fresh water and allowed to stand for some time in a closed vessel until the insoluble putty has settled. When the solution is clear, it may be decanted and added to the feed water or boiler water as required and the putty thrown away. Unslaked lime shall be supplied in air-tight tins, and it is absolutely essential that it shall not be left exposed to the air longer than necessary, as it possesses a great affinity for, and readily absorbs, carbonic-acid gas.

Section II.—Feed-Water Apparatus

PART 1.—FEED-WATER HEATERS.

(A) CARE AND OPERATION.

6–130. Feed-water heaters serve two purposes—the economical one, heating the water before it enters the boiler, and the purifying one, removing to some extent the entrained air and gases from the water. **Functions of feed-water heater.**

6–131. The primary function of a feed heater is to raise the temperature of boiler feed water before it reaches the boiler by use of exhaust steam. This heating is generally done by passing the feed water through tubes contained in a large shell and sending exhaust steam into the shell and around the tubes. Much of the heat in auxiliary exhaust steam is utilized in the feed heaters, the distilling plant, and lower pressure stages of main propelling machinery. The remaining heat passing to the condensers is an absolute loss as it goes overboard in the form of heated circulating water. **Primary function of feed-water heater.**

6–132. The secondary function of the heater is to cause some of the entrained air to be released from the feed water and then to remove it from the system. Therefore a fitting must be installed to accomplish this removal. This fitting should take off from the top of the hottest part of the system—the feed line at the point where the water leaves the heater. **Secondary function of feed heater.**

6–133. (1) The latest installations are fitted with air chambers connected to the feed line near the heater. To this chamber is fitted a water glass and an air cock. The water glass shows the amount of water in the air chamber, thus indicating the amount of air therein. The air cock is fitted in order that the air released from the feed water can be discharged from the system. This discharge can be accomplished intermittently, or the cock can be opened just enough to allow the air to sputter out. **Air chambers.**

(2) Ships not fitted with the above air chamber should install a pipe leading from the top of the hottest part of the water space in the feed heater to the feed tank. This vent pipe should be one-half inch pipe, and the valve on this pipe should always be kept sufficiently open to allow some water to return from the feed heater to the feed tank. Tests have been reported to show that this arrangement will remove most of the air from the feed water. The temperature of the water in the feed heater must be kept as high as possible to secure the greatest advantages from this device. **Fit vent when no air chamber is installed.**

6–134 (1). Feed-water heaters are of two types, the open and the closed. The closed type is used almost universally in the United States Navy, and it alone will be discussed in this manual. There are two kinds of closed heaters, the low-pressure and the high-pressure. **Classes of feed water heaters.** **Kinds of closed heaters.**

(2) Low-pressure heaters are those installed in the feed suction line. With this kind of heater two pumps are necessary, one, commonly known as the "booster," or "hot well" pump, to pump the water from the feed tanks through the heater, and another, the main feed pump, to pump the water from the heater to the boiler.

(3) High-pressure heaters are installed in the feed discharge lines; the feed pump takes the water from the feed tank and discharges through the heater to the boiler.

Low-pressure heaters. 6–135. With low-pressure heaters the pressure put on by the booster pump is generally about 20 pounds, and the temperature is limited by the highest temperature attainable without causing the feed pump to lose suction. When low-pressure heaters are used, with a pressure of exhaust steam that is not excessive (say 10 pounds gauge), the feed water should reach a temperature of more than 200° F. Due to water boiling on the suction side of the pump, loss of suction is caused if the temperature goes above the boiling point. However, with feed pumps in good condition, feed water may be dependably handled with the temperature around 206° F. to 210° F. In view of the resulting economy the higher temperature should always be maintained if possible.

High-pressure heaters. 6–136. In the high-pressure type of feed heaters the pressure on the water side is the pressure in the boilers feed line. Due to the fact that the feed water has already passed through the feed pump, its temperature is limited only by the amount of heat available in the auxiliary exhaust, which in turn depends on the back pressure carried. To withstand the pressure of the feed water the heads and tubes of this type of heater are tested to about 500 pounds, and to withstand the pressure of the auxiliary exhaust the shell is tested to a pressure of from 50 to 75 pounds.

Types of closed heaters. 6–137. The principal types of closed heaters in the United States service are:

(*a*) Straight tube.
(*b*) U tube.
(*c*) Film heaters.
(*d*) Multicoil heaters.

Economy due to heating feed water with exhaust steam. 6–138. When using exhaust steam to heat feed water, it has been found, both in theoretical calculations and in practical tests, that for every 10° F. rise in temperature of feed water there is a 1 per cent reduction in the amount of heat necessary to produce the steam with a corresponding reduction in fuel used.

General features of operation. 6–139. (1) (*a*) With a properly designed heater of the high-pressure type and with the heater clean and in proper condition, the temperature of water leaving the heater when steaming at normal speeds should be within 10° of that of the exhaust steam. The temperature of steam at 10 pounds gauge, or 25 pounds absolute, is 240° F. Hence with a 10-pound back pressure and when steaming under the best conditions the feed water should leave the heater at about 230° F. Under all circumstances the feed water should be kept as hot as possible, the exact pressure at which to carry the exhaust steam being left to the discretion of the engineer officer, who should determine the point of maximum efficiency. In accomplishing this end he must remember that all the auxiliary machinery must work against the back pressure and that when operating turbine-driven auxiliaries operating noncondensing the back pressure shall never exceed 15 pounds gauge.

(*b*) Whether to increase the pressure a few pounds or to operate with water at a little lower temperature, is a point which the engineer officer must determine by experiment.

Water seal in heaters. (2) Under ordinary cruising conditions a water seal should always be maintained on the steam side of the heater. This can be done by

keeping water in sight in the gauge glass. However, if the amount of steam is such that the feed heater, evaporators, receivers, and low-pressure stages of the turbines can not take care of the exhaust steam it should be allowed to blow through the drains of the feed-water heater, but only at such a rate as will allow the desired back pressure to be maintained.

(3) The drain from the heater should always be led to the main feed and filter tank, unless the water in the tank gets too hot for working conditions, when it should be sent to the condenser. **Drains from heaters.**

6–140. With the U-tube, straight tube, and film type of heater considerable trouble is experienced in maintaining tight joints. Hence, to prevent loss of feed water, care must be taken that the gasket seatings are always kept in excellent condition and that the gaskets are made of only the best grade of high-pressure sheet packing. Bolts and nuts give better results than studs when making up the heavy flange header joints. **Tightness of heaters.**

6–141. (1) In the straight-tube type tubes are expanded in the tube sheets, and expansion is cared for by an expansion ring in the shell. The heater must be so secured in place that one end is free to move. **Expansion of shell.**

(2) Straight-tube heaters are generally fitted with retarders. This device is a flat strip of brass twisted at regular intervals along its length, inserted in the tube and firmly secured at one end. The retarders extend the entire length of the tubes, break up the "core" of the water, and, by the whirling motion given to the water, lessen the thickness of the dead film of water on the skin of the tubes. **Retarders.**

(3) The retarders collect some of the grease and dirt contained in the feed water and should be removed from the tubes and cleaned each time that the heater is cleaned.

6–142. With the film type of heater care must be taken that there is always sufficient clearance between the inner and outer tubes. Should the tubes foul each other due to unequal expansion, sagging, or other distortion of the metal, there will occur a drop in the efficiency of the feed heater. **Clearance between tubes in film type.**

6–143. (1) In the multicoil heater the coils are secured to the manifolds by means of ground-joint unions, thus eliminating the use of large gaskets under heavy pressure. The feed water passes through the manifolds and coils and the auxiliary exhaust goes into the top of the shell, being drained out at the bottom. **The multicoil heater.**

(2) The operation is the same as that of any other high-pressure types. It is fitted with a vacuum breaking valve, which signals if the heater is placed under vacuum due to failure of the automatic relief valve to main condenser on the opening of any condenser connection to the auxiliary exhaust line.

6–144. If the drain discharge from a heater becomes excessive, a leaky tube should be looked for. **Excessive heater drains.**

6–145. The relief valve on the heater shall be tested weekly and kept in excellent condition at all times. Should a large tube leak occur and the relief valve fail to function, the shell of the heater would be ruptured. **Test relief valve.**

6–146. The air chamber is fitted in order that the air released by heating the water can be extracted from the feed water. The personnel should be properly instructed in its use. (See arts. 6–133 and 6–148.) **Air chambers.**

Baffles.

6–147. Where baffles are fitted in feed-water heaters, they must be examined at regular intervals to insure that they are in good condition. If the baffles, which direct the flow of the water, leak, a quantity of the water goes directly through the heater, having passed through the tubes but a single time, causing a drop in the feed-water temperature; if the baffles installed in the steam space are improperly fitted or leak badly, the steam remains in contact with the heating surface a shorter time than designed, causing a loss in efficiency.

Air chambers on evaporator feed-water heaters.

6–148. Evaporator feed-water heaters should always be fitted with air chambers or air traps to release the air, chlorine, ammonia, and other gases generated by heating the sea water. The evaporator feed water should be heated to a high temperature in order to release as great a portion of the contained gases as is possible. The drain should have a fitting for drawing samples of water. These samples should be frequently tested for salt, the presence of which indicates a leaky heater.

Zincs.

6–149. Zincs should always be fitted in heaters. For method of securing, see article 6–187. They should be inspected quarterly and replaced when badly disintegrated.

(B) REPAIRS.

6–160. A sample repair guide list is given below:

Feed-water heater.

Type.............................. No.......................

(Date)............................

	Done.	Not done.
1. Assemble drawings		
2. Boil out		
3. Inspect steam side		
(a) Examine, clean, repair, renew, test—		
1. Tubes		
2. Baffles		
3. Shell		
4. Fittings		
4. Inspect water side		
(a) Examine, clean, repair, renew, test—		
1. Tubes		
2. Retarders		
3. Zincs		
(b) Check clearance between inner and outer tubes (Film type)		
5. Inspect joints and gaskets		
6. Reassemble		
(a) Test—		
1. Shell (hydrostatic test at designed pressure)		
2. Coils and headers (hydrostatic test at designed pressure)		

Designed clearances.	Present clearance.

Cleaning heaters.

6–161. All heaters should be boiled out with Navy Standard Boiler Compound at regular intervals. The length of time varies between cleanings, depending upon the condition of the plant, the kind of feed

water used, and the amount of steaming done. However, if trouble is experienced in getting hot feed water with moderate back pressure, the heaters should be examined, and immediately cleaned if found covered on either side of the heating surfaces with oil or grease or other foreign matter.

Precautions to make heaters tight.

6–162. As the tubes are subject to a very high pressure, they should be carefully expanded or packed. All joints must be carefully made up. (See arts. 6–140 and 6–143.)

PART 2.—FEED AND FILTER TANKS.

(A) OPERATION, CARE AND REPAIR.

Features of feed and filter tanks.

6–180. (1) Feed and filter tanks are installed as a reservoir for the condensate from the condenser and drains from the various machinery units throughout an engineering establishment, and to remove from the water some of the entrained air. The tanks are divided into two compartments separated by a horizontal plate. The upper part is known as the filter tank and contains filtering material, and the lower part is used as a feed tank. There is an overflow to the bilge or reserve feed tanks.

Purpose of vent on feed and filter tanks.

(2) In order to get rid of air released in the main feed and filter tank and to prevent the accumulation of excessive pressure, vents to the atmosphere are provided. Care shall be taken that these vents do not become clogged.

Kind and use of filtering material.

6–181. (1) The best filtering materials are Turkish toweling, burlap, linen, and loofa sponges. Woolen materials rot easily. Marine sponges are liable to clog the holes in the perforated plates.

(2) Toweling, linen, and burlap are the materials generally used in grease extractors and filters. Loofa sponges are used in the filter compartment of the main feed tanks.

6–182. Loofa sponges when used in a filter tank should be strung on a soft copper or brass wire to facilitate their removal and to prevent any getting adrift through carelessness in handling when being removed.

Precautions with and care of filtering material.

6–183. (1) Great care must be taken that the strainers and holes in the perforated plates of the filter compartment do not become clogged with parts of the filtering material. In order to avoid this trouble the feed and filter tank should be inspected and cleaned quarterly or oftener depending upon amount of steaming done and the condition of the plant as a whole. If the filtering material is allowed to remain installed until disintegration takes place, small pieces of grease-soaked material will be carried through the system.

(2) When it is found that the efficiency of the filtering material is reduced by impregnation with grease, it should be removed, run through wringers to squeeze out the greater portion of the grease, and then boiled out in hot lye water of moderate strength. This cleaning may be done once or twice, but thereafter the material should be renewed. (See art. 6–64.)

Machinery drains led to feed tank.

6–184. (1) The feed tank temperature is important from an economical standpoint. The water should be as hot as can be safely handled by the feed pumps, but should not be permitted to boil, as the resultant waste of water by vaporizing in the tank and escaping through the vent pipe is too great. The exact temperature must be determined

for each special installation and depends upon the location of tank and pumps and length of vapor line. In installations where rotary pumps are used, the temperature of the water in the feed and filter tanks should not exceed 140° F. The heating of the water should be accomplished by having machinery drains led to the tank at all times. Should the water become too hot, it usually is due to opened drains or by passes or to the blowing through of faulty traps. If necessary a part of the drainage water will then have to be taken to the condenser until the fault is located and rectified.

(2) Fixed thermometers where fitted should always be kept in place and in good condition.

Water level in feed tank. 6–185. (1) The water in the feed tank must never be allowed to fall as low as the level of the feed suction pipe.

(2) The feed tank gauge glass must be kept clean and in good condition at all times.

Strainers in feed tanks. 6–186. (1) Great care must be taken in inspecting the strainer usually fitted over the inlet to the feed suction to see that it is structurally strong and in good condition. It should be so constructed that should it come to pieces none of the parts can obstruct the suction. Should this opening become clogged, it can only be cleared by cutting out the feed tank, removing the water, and opening the tank. The same instructions apply to any device fitted for automatically closing the suction in case of low water in the feed tank.

(2) When a new strainer is fitted in the feed tank, great care must be taken to determine that it corresponds to the dimensions specified on the plans. Special attention must be taken to determine that the combined area of the small holes in the strainer is 50 per cent greater than the area of the pipe connection in which it is fitted.

Use of zincs. 6–187. (1) Zinc protectors shall be fitted in the feed tanks. Not only must the zinc be well secured to the feed tank to get good metallic contact, but the joint between the bolt and the zinc must be made water tight by the use of red-lead putty.

(2) Zincs and scrap iron may be suspended in feed tanks to absorb oxygen. This procedure is especially valuable when there is no feed heater installed.

6–190. Example repair guide list is given below:

Main feed and filter tank.

Type.................................No...........................

(Date)...........................

	Done.	Not done.
1. Assemble drawings..		
2. Boil out..		
3. Inspect tank..		
(a) Examine, clean, repair, renew, test—		
1. Interior of tank..		
2. Plates..		
3. Strainers..		
4. Filtering material..		
5. Relief valve..		
6. Internal piping..		
7. Zincs..		

PART 2—GREASE EXTRACTORS.

(A) OPERATION, CARE AND REPAIR.

6–200. The filtering material in grease extractors should be kept clean at all times. Careful attention should be paid to the pressure gage, and, should the pressure on the discharge side of the extractor be 10 or more pounds lower than the intake side, the filtering material should be taken out and cleaned or renewed. (See art. 6–64.) **Use of pressure gauge reading.**

6–201. With the rapid growth in the use of the turbines for main engines and also for auxiliaries, the use of the grease extractor is gradually becoming less and less, as with turbine machinery much less grease enters the steam spaces later to find its way to the feed water. **Grease extractors on turbine installations.**

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